US009157177B2

# (12) United States Patent
Buendia et al.

(10) Patent No.: US 9,157,177 B2
(45) Date of Patent: Oct. 13, 2015

(54) **LAUNDRY TREATING APPLIANCE AND METHOD OF CONTROL**

(75) Inventors: **Ali R. Buendia**, Saint Joseph, MI (US); **Karl David McAllister**, Stevensville, MI (US)

(73) Assignee: **Whirlpool Corporation**, Benton Harbor, MI (US)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 945 days.

(21) Appl. No.: **13/332,951**

(22) Filed: **Dec. 21, 2011**

(65) **Prior Publication Data**

US 2013/0160216 A1 Jun. 27, 2013

(51) **Int. Cl.**
***D06F 33/02*** (2006.01)
***D06F 37/30*** (2006.01)
***D06F 39/00*** (2006.01)

(52) **U.S. Cl.**
CPC .............. ***D06F 33/02*** (2013.01); ***D06F 37/304*** (2013.01); ***D06F 39/003*** (2013.01); *D06F 2202/06* (2013.01); *D06F 2204/06* (2013.01); *Y02B 40/52* (2013.01)

(58) **Field of Classification Search**
CPC ..... D06F 33/02; D06F 39/003; D06F 37/304; D06F 2202/06; D06F 2204/06
USPC ..................... 8/158, 159; 68/12.04, 12.23, 24
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,335,524 A 8/1994 Sakane
6,381,791 B1 5/2002 French et al.
6,397,422 B1 6/2002 Maziere
6,581,230 B2 6/2003 Weinmann
6,834,407 B2 12/2004 Stephens
7,471,054 B2 12/2008 Marioni
8,499,392 B2 * 8/2013 Suel et al. ......................... 8/159
2004/0211009 A1 * 10/2004 Murray et al. .................... 8/159
2005/0204482 A1 * 9/2005 Murray et al. .................... 8/158
2007/0113598 A1 * 5/2007 Jun et al. ......................... 68/140
2008/0115295 A1 * 5/2008 Vadakkeveedu et al. ......... 8/159
2009/0266113 A1 * 10/2009 Musser et al. ............... 68/12.06
2010/0000022 A1 1/2010 Hendrickson et al.
2010/0000024 A1 1/2010 Hendrickson et al.
2010/0000264 A1 1/2010 Luckman et al.
2010/0000573 A1 1/2010 Hendrickson et al.
2010/0000581 A1 1/2010 Doyle et al.
2010/0000586 A1 1/2010 Hendrickson
2010/0251487 A1 10/2010 Bolduan et al.
2010/0263136 A1 10/2010 Ashrafzadeh et al.
2011/0016738 A1 1/2011 Ashrafzadeh et al.
2011/0030149 A1 2/2011 Cho et al.
2011/0030150 A1 2/2011 Ashrafzadeh et al.
2011/0113569 A1 * 5/2011 Ashrafzadeh et al. ............ 8/159
2012/0266389 A1 10/2012 Ihne et al.

FOREIGN PATENT DOCUMENTS

DE 3436786 A1 4/1986
DE 4205816 A1 9/1993
DE 19819554 A1 11/1999

(Continued)

OTHER PUBLICATIONS

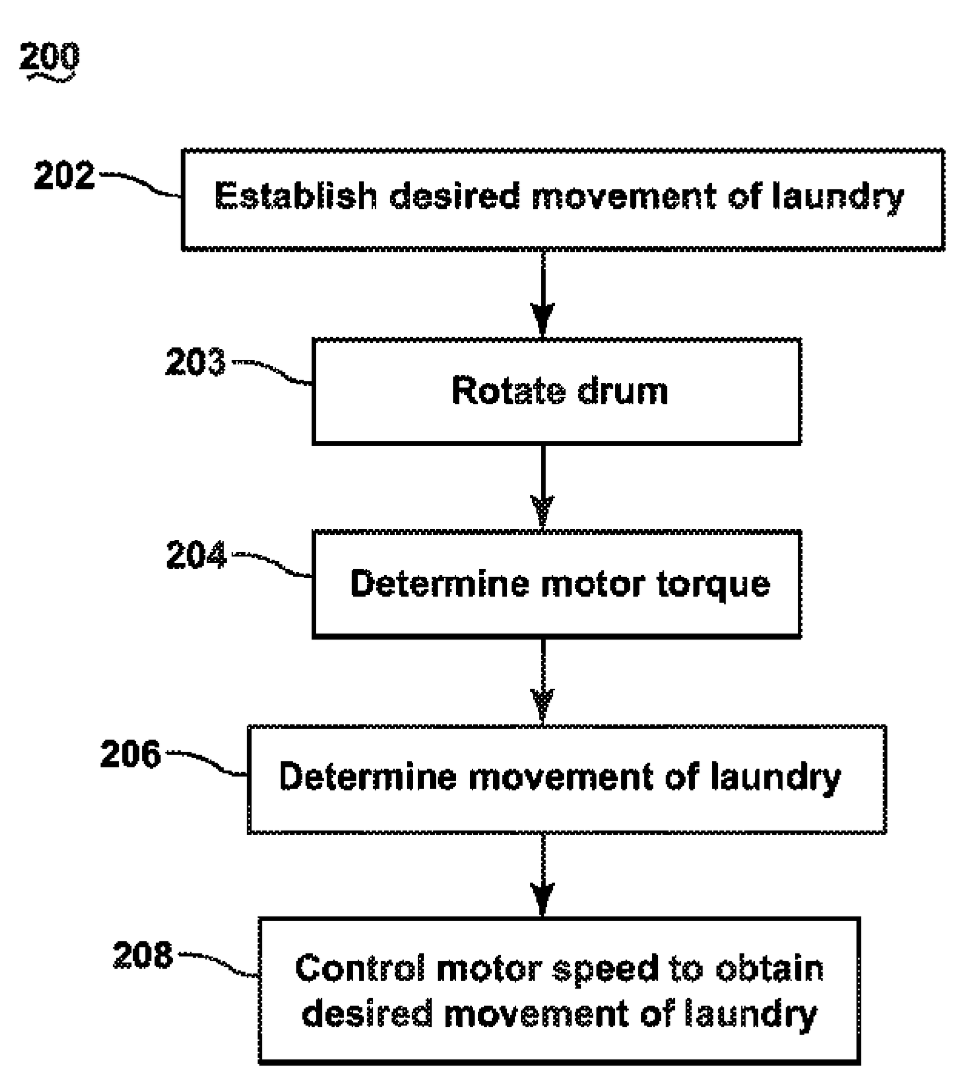
German Search Report for DE102012110180, Jul. 22, 2013.

*Primary Examiner* — Joseph L Perrin

(57) **ABSTRACT**

A method of operating a laundry treating appliance to control a rotational speed of a drum to move the laundry within the drum according to a predetermined category of movement.

**11 Claims, 5 Drawing Sheets**



(56) **References Cited**

FOREIGN PATENT DOCUMENTS

| | | | |
|---|---|---|---|
| DE | 102007057331 | A1 | 6/2009 |
| DE | 102010016454 | A1 | 2/2011 |
| DE | 102010016875 | A1 | 2/2011 |
| EP | 0219422 | A1 | 4/1987 |
| EP | 0428469 | A2 | 5/1991 |
| EP | 1103648 | A2 | 5/2001 |
| EP | 1734167 | A1 | 12/2006 |
| FR | 2655363 | A1 | 6/1991 |
| JP | 2009066095 | A | 4/2009 |
| JP | 2009297123 | A | 12/2009 |
| WO | 2006129157 | A1 | 12/2006 |

* cited by examiner

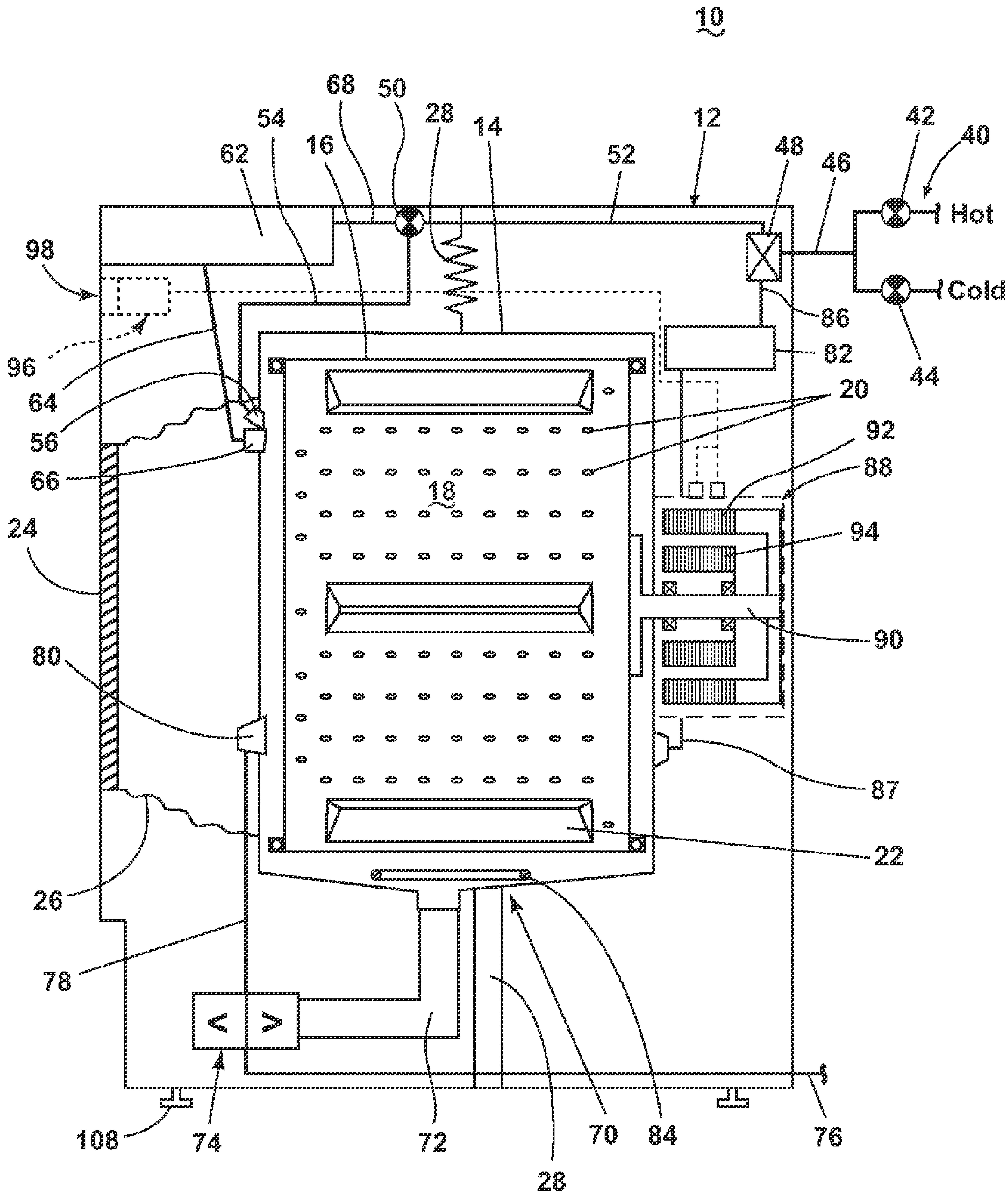

10
68
50
28
14
12
54
16
62
52
48
46
42
40
Hot
Cold
98
86
82
44
96
64
56
66
20
92
88
18
24
94
90
80
87
22
26
78
70
84
72
74
108
76
28

Fig. 1

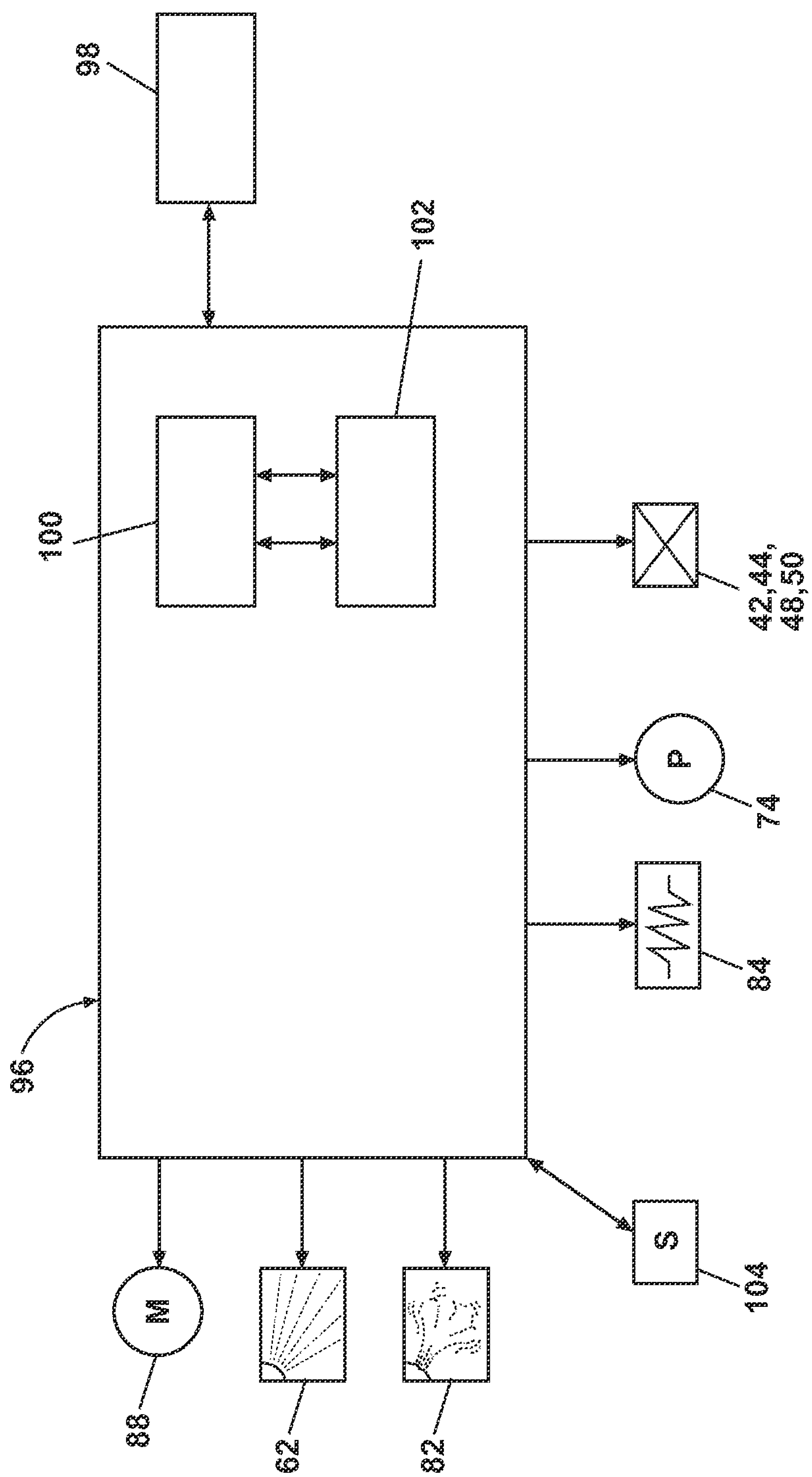



Fig. 2

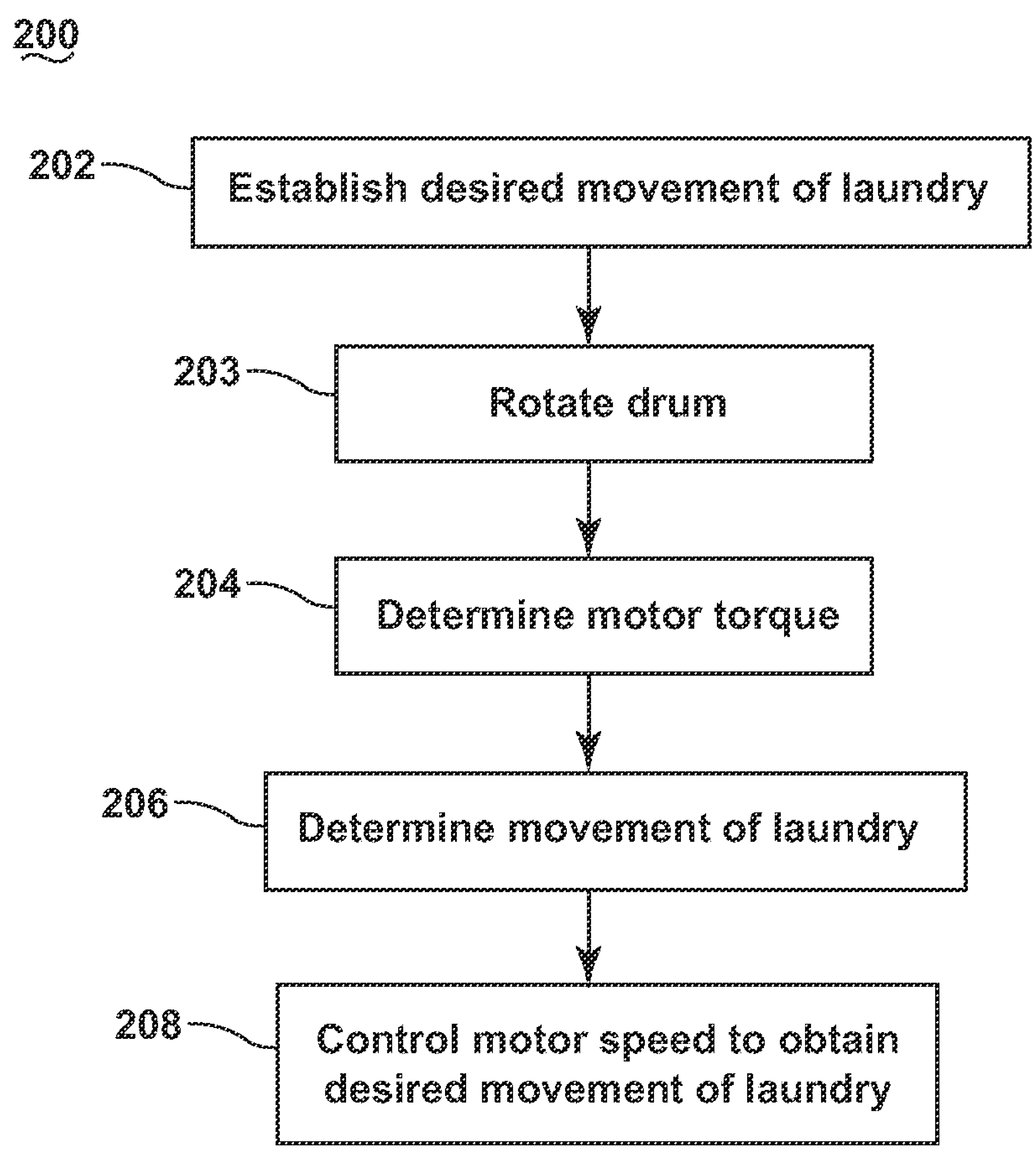

200
202
Establish desired movement of laundry
203
Rotate drum
204
Determine motor torque
206
Determine movement of laundry
208
Control motor speed to obtain desired movement of laundry

Fig. 3

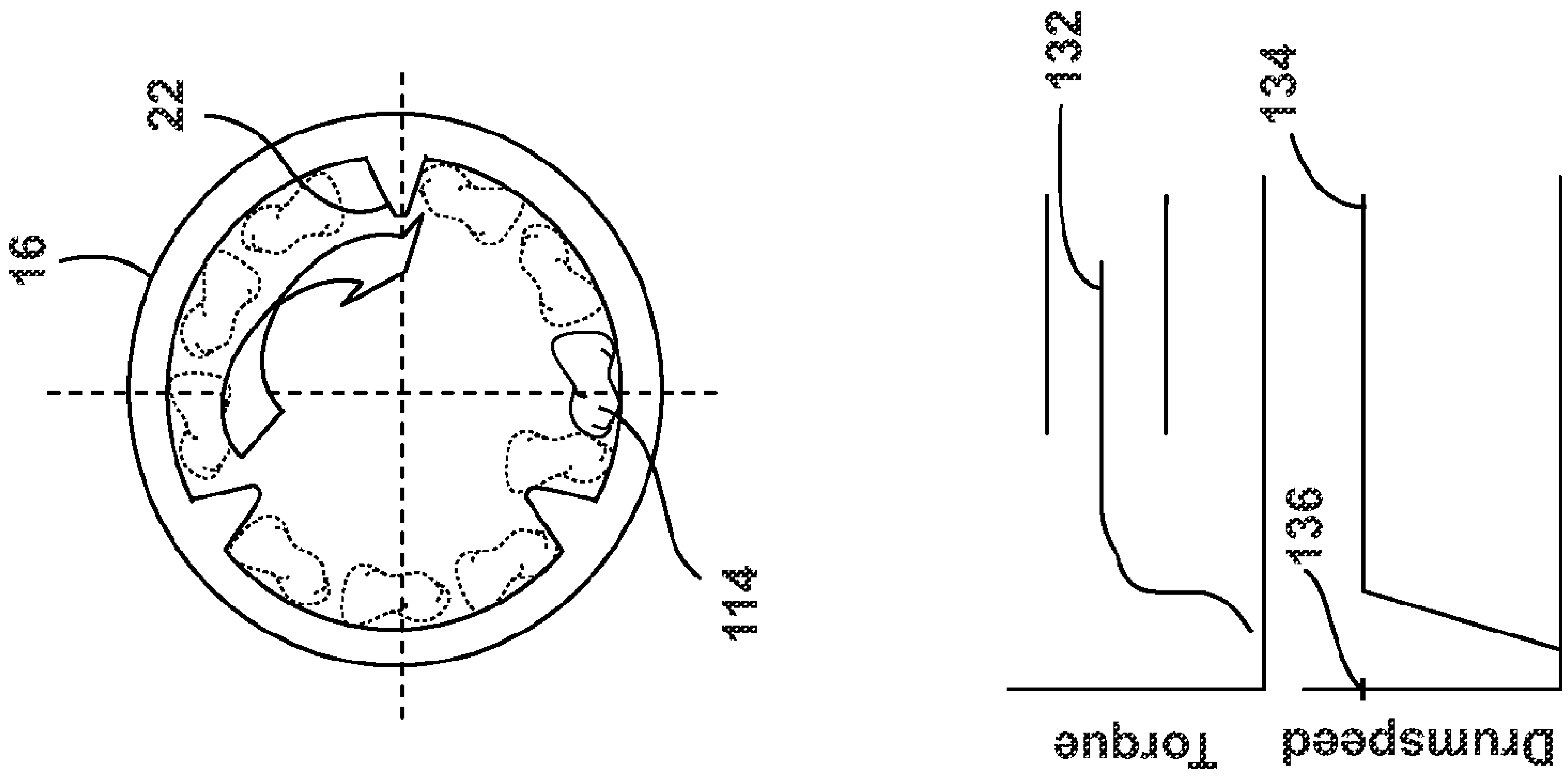



Fig. 6

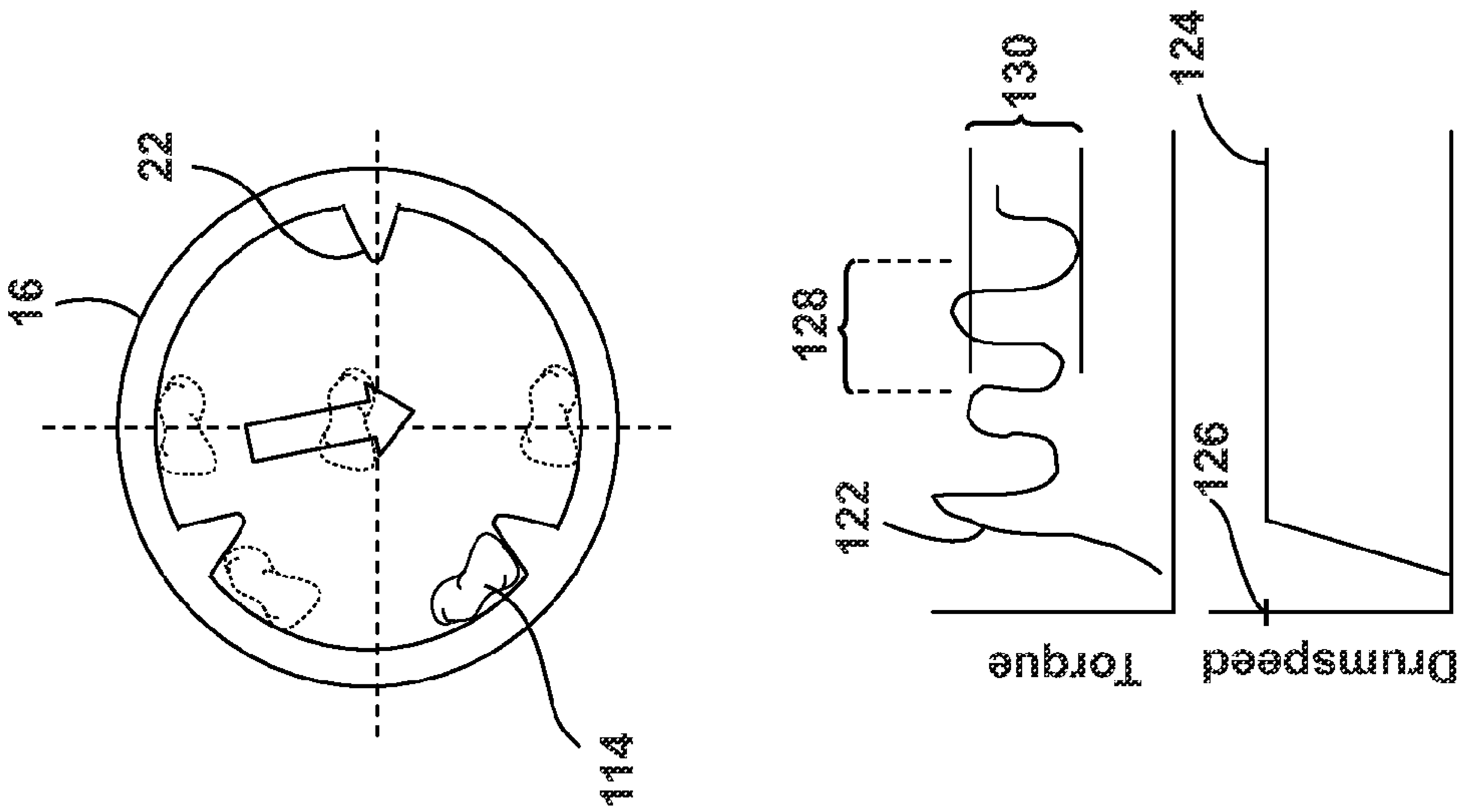



Fig. 5

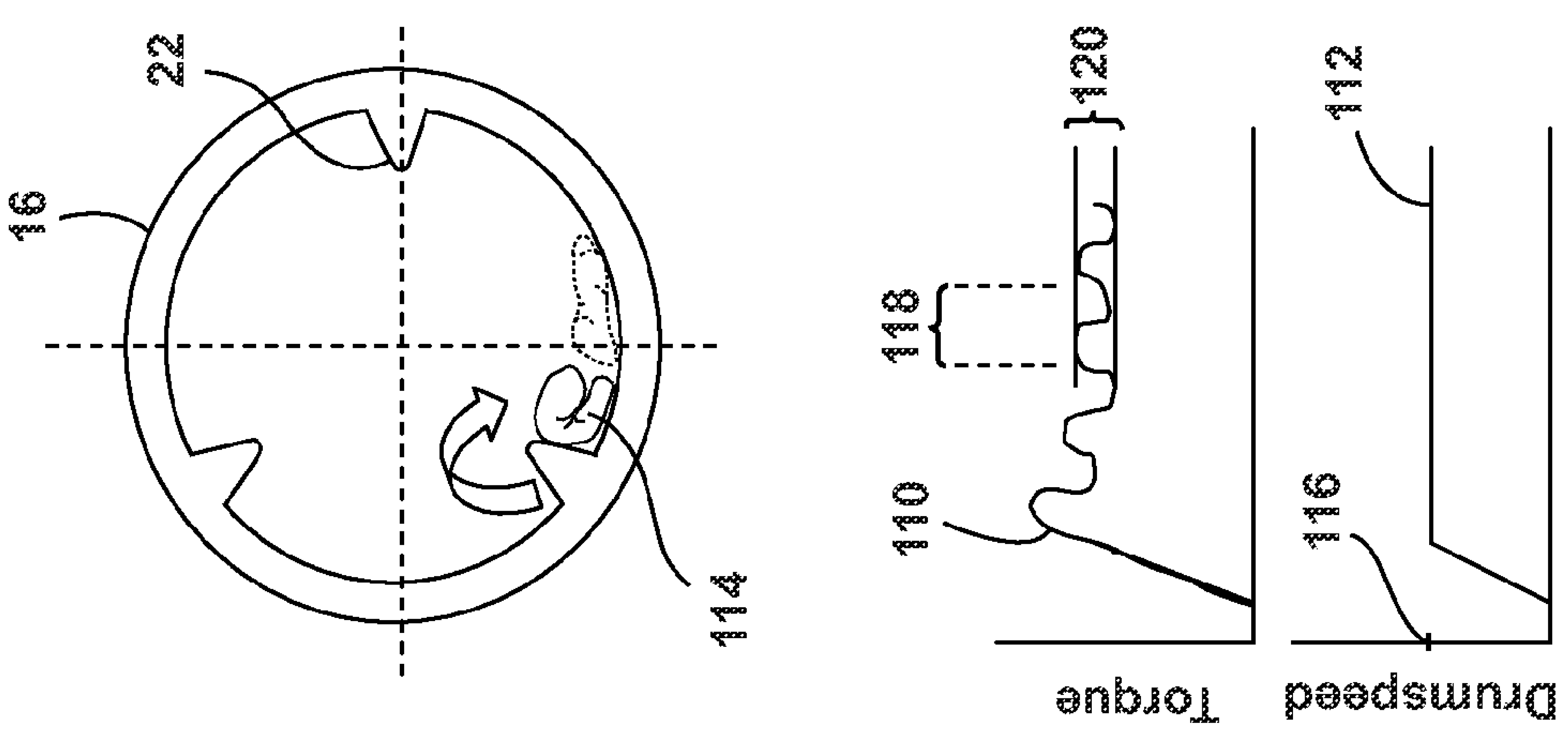



Fig. 4

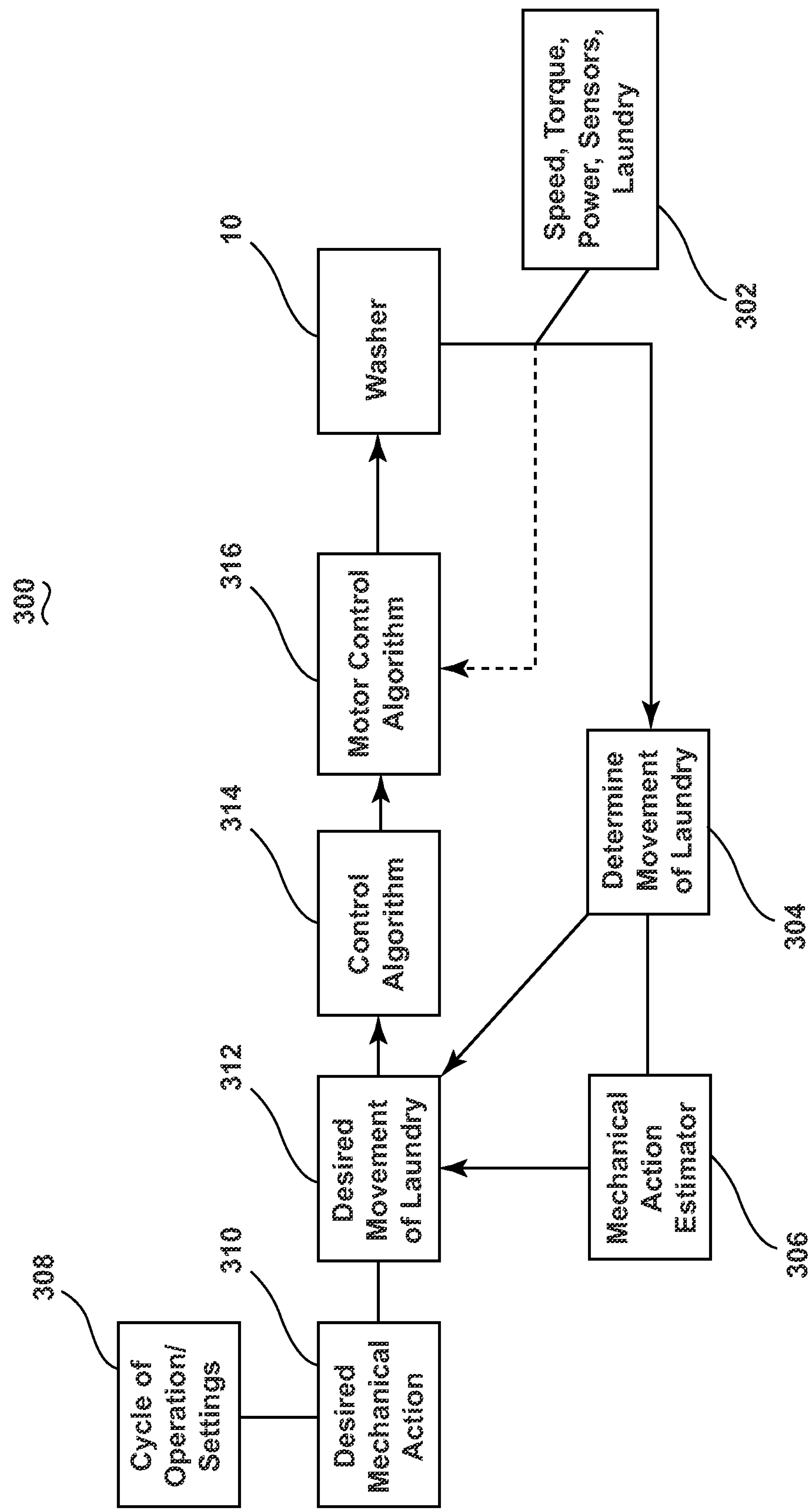

300
Cycle of Operation/ Settings
308
Desired Mechanical Action
310
Desired Movement of Laundry
312
Control Algorithm
314
Motor Control Algorithm
316
Washer
10
Speed, Torque, Power, Sensors, Laundry
302
Determine Movement of Laundry
304
Mechanical Action Estimator
306

Fig. 7

# LAUNDRY TREATING APPLIANCE AND METHOD OF CONTROL

## BACKGROUND

Laundry treating appliances, such as clothes washers, refreshers, and non-aqueous systems, may have a configuration based on a rotating drum that defines a treating chamber in which laundry items are placed for treating. The laundry treating appliance may have a controller that implements a number of pre-programmed cycles of operation having one or more operating parameters. The controller may control a motor to rotate the drum according to one of the pre-programmed cycles of operation. The controller may control the motor to rotate the drum at the same speeds for a give pre-programmed cycle of operation regardless of the characteristics of the laundry items or changes in the system.

## BRIEF SUMMARY

According to an embodiment of the invention, a method of operating a laundry treating appliance having a drum at least partially defining a treating chamber for receiving a laundry for treatment, a motor operably coupled to and rotating the drum, a controller coupled to and controlling the motor, and a user interface operably coupled to the controller, wherein the controller controls the motor according to a cycle of operation selected via the user interface, comprises establishing a desired movement of the laundry within the treating chamber, controlling the speed of the motor to control the rotational speed of the drum by the controller providing a speed control signal to the motor and receiving by the controller a torque signal indicative of the torque of the motor. The controller may monitor the amplitude and frequency of a ripple in the torque signal, determine a category of movement of the laundry from a predetermined group of movement categories based on the monitored amplitude and frequency, and control the speed of the motor until the determined movement of the laundry satisfies the desired movement of the laundry.

## BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. **1** is a schematic view of a laundry treating appliance in the form of a washing machine according to a first embodiment of the invention.

FIG. **2** is a schematic of a control system of the laundry treating appliance of FIG. **1** according to the first embodiment of the invention.

FIG. **3** is a flow chart illustrating a method of controlling a rotational speed of a drum of a washing machine according to a second embodiment of the invention.

FIG. **4** is a schematic illustration of a motor torque and drum speed signal corresponding to a movement of an article of laundry in a drum of a washing machine according to a third embodiment of the invention.

FIG. **5** is a schematic illustration of a motor torque and drum speed signal corresponding to a movement of an article of laundry in a drum of a washing machine according to a fourth embodiment of the invention.

FIG. **6** is a schematic illustration of a motor torque and drum speed signal corresponding to a movement of an article of laundry in a drum of a washing machine according to a fifth embodiment of the invention.

FIG. **7** is a schematic of a control system for controlling a rotational speed of a drum in a washing machine according to according to a sixth embodiment of the invention.



## DETAILED DESCRIPTION

FIG. **1** is a schematic view of a laundry treating appliance according to a first embodiment of the invention. The laundry treating appliance may be any appliance which performs a cycle of operation to clean or otherwise treat items placed therein, non-limiting examples of which include a horizontal or vertical axis clothes washer; a combination washing machine and dryer; a tumbling or stationary refreshing/revitalizing machine; an extractor; a non-aqueous washing apparatus; and a revitalizing machine.

The laundry treating appliance of FIG. **1** is illustrated as a washing machine **10**, which may include a structural support system comprising a cabinet **12** which defines a housing within which a laundry holding system resides. The cabinet **12** may be a housing having a chassis and/or a frame, defining an interior enclosing components typically found in a conventional washing machine, such as motors, pumps, fluid lines, controls, sensors, transducers, and the like. Such components will not be described further herein except as necessary for a complete understanding of the invention.

The laundry holding system comprises a tub **14** supported within the cabinet **12** by a suitable suspension system and a drum **16** provided within the tub **14**, the drum **16** defining at least a portion of a laundry treating chamber **18**. The drum **16** may include a plurality of perforations **20** such that liquid may flow between the tub **14** and the drum **16** through the perforations **20**. A plurality of baffles **22** may be disposed on an inner surface of the drum **16** to lift the laundry load received in the treating chamber **18** while the drum **16** rotates. It is also within the scope of the invention for the laundry holding system to comprise only a tub with the tub defining the laundry treating chamber.

The laundry holding system may further include a door **24** which may be movably mounted to the cabinet **12** to selectively close both the tub **14** and the drum **16**. A bellows **26** may couple an open face of the tub **14** with the cabinet **12**, with the door **24** sealing against the bellows **26** when the door **24** closes the tub **14**.

The washing machine **10** may further include a suspension system **28** for dynamically suspending the laundry holding system within the structural support system.

The washing machine **10** may further include a liquid supply system for supplying water to the washing machine **10** for use in treating laundry during a cycle of operation. The liquid supply system may include a source of water, such as a household water supply **40**, which may include separate valves **42** and **44** for controlling the flow of hot and cold water, respectively. Water may be supplied through an inlet conduit **46** directly to the tub **14** by controlling first and second diverter mechanisms **48** and **50**, respectively. The diverter mechanisms **48**, **50** may be a diverter valve having two outlets such that the diverter mechanisms **48**, **50** may selectively direct a flow of liquid to one or both of two flow paths. Water from the household water supply **40** may flow through the inlet conduit **46** to the first diverter mechanism **48** which may direct the flow of liquid to a supply conduit **52**. The second diverter mechanism **50** on the supply conduit **52** may direct the flow of liquid to a tub outlet conduit **54** which may be provided with a spray nozzle **56** configured to spray the flow of liquid into the tub **14**. In this manner, water from the household water supply **40** may be supplied directly to the tub **14**.

The washing machine **10** may also be provided with a dispensing system for dispensing treating chemistry to the treating chamber **18** for use in treating the laundry according to a cycle of operation. The dispensing system may include a dispenser **62** which may be a single use dispenser, a bulk dispenser or a combination of a single and bulk dispenser. Non-limiting examples of suitable dispensers are disclosed in U.S. Pub. No. 2010/0000022 to Hendrickson et al., filed Jul. 1, 2008, entitled "Household Cleaning Appliance with a Dispensing System Operable Between a Single Use Dispensing System and a Bulk Dispensing System," U.S. Pub. No. 2010/0000024 to Hendrickson et al., filed Jul. 1, 2008, entitled "Apparatus and Method for Controlling Laundering Cycle by Sensing Wash Aid Concentration," U.S. Pub. No. 2010/0000573 to Hendrickson et al., filed Jul. 1, 2008, entitled "Apparatus and Method for Controlling Concentration of Wash Aid in Wash Liquid," U.S. Pub. No. 2010/0000581 to Doyle et al., filed Jul. 1, 2008, entitled "Water Flow Paths in a Household Cleaning Appliance with Single Use and Bulk Dispensing," U.S. Pub. No. 2010/0000264 to Luckman et al., filed Jul. 1, 2008, entitled "Method for Converting a Household Cleaning Appliance with a Non-Bulk Dispensing System to a Household Cleaning Appliance with a Bulk Dispensing System," U.S. Pub. No. 2010/0000586 to Hendrickson, filed Jun. 23, 2009, entitled "Household Cleaning Appliance with a Single Water Flow Path for Both Non-Bulk and Bulk Dispensing," and application Ser. No. 13/093,132, filed Apr. 25, 2011, entitled "Method and Apparatus for Dispensing Treating Chemistry in a Laundry Treating Appliance," which are herein incorporated by reference in full.

Regardless of the type of dispenser used, the dispenser **62** may be configured to dispense a treating chemistry directly to the tub **14** or mixed with water from the liquid supply system through a dispensing outlet conduit **64**. The dispensing outlet conduit **64** may include a dispensing nozzle **66** configured to dispense the treating chemistry into the tub **14** in a desired pattern and under a desired amount of pressure. For example, the dispensing nozzle **66** may be configured to dispense a flow or stream of treating chemistry into the tub **14** by gravity, i.e. a non-pressurized stream. Water may be supplied to the dispenser **62** from the supply conduit **52** by directing the diverter mechanism **50** to direct the flow of water to a dispensing supply conduit **68**.

Non-limiting examples of treating chemistries that may be dispensed by the dispensing system during a cycle of operation include one or more of the following: water, enzymes, fragrances, stiffness/sizing agents, wrinkle releasers/reducers, softeners, antistatic or electrostatic agents, stain repellants, water repellants, energy reduction/extraction aids, antibacterial agents, medicinal agents, vitamins, moisturizers, shrinkage inhibitors, and color fidelity agents, and combinations thereof.

The washing machine **10** may also include a recirculation and drain system for recirculating liquid within the laundry holding system and draining liquid from the washing machine **10**. Liquid supplied to the tub **14** through tub outlet conduit **54** and/or the dispensing supply conduit **68** typically enters a space between the tub **14** and the drum **16** and may flow by gravity to a sump **70** formed in part by a lower portion of the tub **14**. The sump **70** may also be formed by a sump conduit **72** that may fluidly couple the lower portion of the tub **14** to a pump **74**. The pump **74** may direct liquid to a drain conduit **76**, which may drain the liquid from the washing machine **10**, or to a recirculation conduit **78**, which may terminate at a recirculation inlet **80**. The recirculation inlet **80** may direct the liquid from the recirculation conduit **78** into the drum **16**. The recirculation inlet **80** may introduce the liquid into the drum **16** in any suitable manner, such as by spraying, dripping, or providing a steady flow of liquid. In this manner, liquid provided to the tub **14**, with or without treating chemistry may be recirculated into the treating chamber **18** for treating the laundry within.

The liquid supply and/or recirculation and drain system may be provided with a heating system which may include one or more devices for heating laundry and/or liquid supplied to the tub **14**, such as a steam generator **82** and/or a sump heater **84**. Liquid from the household water supply **40** may be provided to the steam generator **82** through the inlet conduit **46** by controlling the first diverter mechanism **48** to direct the flow of liquid to a steam supply conduit **86**. Steam generated by the steam generator **82** may be supplied to the tub **14** through a steam outlet conduit **87**. The steam generator **82** may be any suitable type of steam generator such as a flow through steam generator or a tank-type steam generator. Alternatively, the sump heater **84** may be used to generate steam in place of or in addition to the steam generator **82**. In addition or alternatively to generating steam, the steam generator **82** and/or sump heater **84** may be used to heat the laundry and/or liquid within the tub **14** as part of a cycle of operation.

Additionally, the liquid supply and recirculation and drain system may differ from the configuration shown in FIG. **1**, such as by inclusion of other valves, conduits, treating chemistry dispensers, sensors, such as water level sensors and temperature sensors, and the like, to control the flow of liquid through the washing machine **10** and for the introduction of more than one type of treating chemistry.

The washing machine **10** also includes a drive system for rotating the drum **16** within the tub **14**. The drive system may include a motor **88**, which may be directly coupled with the drum **16** through a drive shaft **90** to rotate the drum **14** about a rotational axis during a cycle of operation. The motor **88** may be a brushless permanent magnet (BPM) motor having a stator **92** and a rotor **94**. Alternately, the motor **88** may be coupled to the drum **16** through a belt and a drive shaft to rotate the drum **16**, as is known in the art. Other motors, such as an induction motor or a permanent split capacitor (PSC) motor, may also be used. The motor **88** may rotate the drum **16** at various speeds in either rotational direction.

The washing machine **10** also includes a control system for controlling the operation of the washing machine **10** to implement one or more cycles of operation. The control system may include a controller **96** located within the cabinet **12** and a user interface **98** that is operably coupled with the controller **96**. The user interface **98** may include one or more knobs, dials, switches, displays, touch screens and the like for communicating with the user, such as to receive input and provide output. The user may enter different types of information including, without limitation, cycle selection and cycle parameters, such as cycle options.

The controller **96** may include the machine controller and any additional controllers provided for controlling any of the components of the washing machine **10**. For example, the controller **96** may include the machine controller and a motor controller. Many known types of controllers may be used for the controller **96**. The specific type of controller is not germane to the invention. It is contemplated that the controller is a microprocessor-based controller that implements control software and sends/receives one or more electrical signals to/from each of the various working components to effect the control software. As an example, proportional control (P), proportional integral control (PI), and proportional derivative control (PD), or a combination thereof, a proportional integral derivative control (PID control), may be used to control the various components.

As illustrated in FIG. **2**, the controller **96** may be provided with a memory **100** and a central processing unit (CPU) **102**.

The memory **100** may be used for storing the control software that is executed by the CPU **102** in completing a cycle of operation using the washing machine **10** and any additional software. Examples, without limitation, of cycles of operation include: wash, heavy duty wash, delicate wash, quick wash, pre-wash, refresh, rinse only, and timed wash. The memory **100** may also be used to store information, such as a database or table, and to store data received from one or more components of the washing machine **10** that may be communicably coupled with the controller **96**. The database or table may be used to store the various operating parameters for the one or more cycles of operation, including factory default values for the operating parameters and any adjustments to them by the control system or by user input.

The controller **96** may be operably coupled with one or more components of the washing machine **10** for communicating with and controlling the operation of the component to complete a cycle of operation. For example, the controller **96** may be operably coupled with the motor **88**, the pump **74**, the dispenser **62**, the steam generator **82** and the sump heater **84** to control the operation of these and other components to implement one or more of the cycles of operation.

The controller **96** may also be coupled with one or more sensors **104** provided in one or more of the systems of the washing machine **10** to receive input from the sensors, which are known in the art and not shown for simplicity. Non-limiting examples of sensors **104** that may be communicably coupled with the controller **96** include: a treating chamber temperature sensor, a moisture sensor, a weight sensor, a chemical sensor, a position sensor and a motor torque sensor, which may be used to determine a variety of system and laundry characteristics, such as laundry load inertia or mass.

In one example, one or more load amount sensors **106** may also be included in the washing machine **10** and may be positioned in any suitable location for detecting the amount of laundry, either quantitative (inertia, mass, weight, etc.) or qualitative (small, medium, large, etc.) within the treating chamber **18**. By way of non-limiting example, it is contemplated that the amount of laundry in the treating chamber may be determined based on the weight of the laundry and/or the volume of laundry in the treating chamber. Thus, the one or more load amount sensors **106** may output a signal indicative of either the weight of the laundry load in the treating chamber **18** or the volume of the laundry load in the treating chamber **18**.

The one or more load amount sensors **106** may be any suitable type of sensor capable of measuring the weight or volume of laundry in the treating chamber **18**. Non-limiting examples of load amount sensors **106** for measuring the weight of the laundry may include load volume, pressure, or force transducers which may include, for example, load cells and strain gauges. It has been contemplated that the one or more such sensors **106** may be operably coupled to the suspension system **28** to sense the weight borne by the suspension system **28**. The weight borne by the suspension system **28** correlates to the weight of the laundry loaded into the treating chamber **18** such that the sensor **106** may indicate the weight of the laundry loaded in the treating chamber **18**. In the case of a suitable sensor **106** for determining volume it is contemplated that an IR or optical based sensor may be used to determine the volume of laundry located in the treating chamber **18**.

Alternatively, it has been contemplated that the washing machine **10** may have one or more pairs of feet **108** extending from the cabinet **12** and supporting the cabinet **12** on the floor and that a weight sensor (not shown) may be operably coupled to at least one of the feet **108** to sense the weight borne by that foot **108**, which correlates to the weight of the laundry loaded into the treating chamber **18**. In another example, the amount of laundry within the treating chamber **18** may be determined based on motor sensor output, such as output from a motor torque sensor. The motor torque is a function of the inertia of the rotating drum and laundry. There are many known methods for determining the load inertia, and thus the load mass, based on the motor torque. It will be understood that the details of the load amount sensors are not germane to the embodiments of the invention and that any suitable method and sensors may be used to determine the amount of laundry.

The previously described washing machine **10** may be used to implement one or more embodiments of the invention. The embodiments of the method of the invention may be used to control the operation of the washing machine **10** to control the speed of the motor **88** to control the movement of the laundry within the laundry treating chamber **18** to provide a desired mechanical cleaning action.

Referring now to FIG. **3**, a flow chart of a method **200** for controlling the speed of the motor **88** to control the rotational speed of the drum **16** in the washing machine **10** is illustrated. The sequence of steps depicted for this method and the proceeding methods are for illustrative purposes only, and is not meant to limit any of the methods in any way as it is understood that the steps may proceed in a different logical order or additional or intervening steps may be included without detracting from the invention.

The method **200** starts with assuming that the user has placed one or more laundry articles for treatment within the treating chamber **18** and selected a cycle of operation through the user interface **98**. The method **200** may be implemented during any portion of a cycle of operation or may be implemented as a separate cycle of operation. At **202**, the controller **96** may establish a desired movement of the laundry within the treating chamber **18**. At **203**, the controller **96** may provide a speed control signal to the motor **88** to control the rotational speed of the drum **16**. At **204**, the controller **96** may receive one or more signals from the motor **88** to determine the motor torque during rotation of the drum **16** at **203**. At **206**, the controller **96** may use the determined motor torque to determine the movement of the laundry within the laundry treating chamber **18**. At **208**, the controller **96** may provide one or more additional speed control signals to the motor **88** to control the rotational speed of the drum **16** to obtain the desired movement of the laundry. The method **200** may be repeated one or more times continuously or intermittently throughout the course of a cycle of operation or one or more phases of a cycle of operation, such as a washing phase or rinsing phase, for example.

Establishing the desired movement of the laundry at **202** may be based on imparting a desired amount of mechanical energy to the laundry during the cycle of operation. The amount of mechanical energy may be determined manually, such as by the user through the user interface, and/or automatically, based on the selected cycle of operation and one or more settings for the cycle of operation, such as the amount of laundry, which may include liquid absorbed by the laundry and/or the fabric type of laundry, for example. For example, a normal wash cycle may apply more mechanical energy to the laundry than a delicate cycle. As used herein, liquid absorbed by the laundry includes liquid carried by the laundry fabric and liquid carried within folds or pockets of the laundry articles.

The amount of laundry may be qualitative or quantitative and may be determined manually based on user input through the user interface **98** or automatically by the washing machine

**10**. For example, a qualitative determination of the laundry amount may include determining whether the laundry is a small, medium or large load. A quantitative determination may include determining a weight or volume of the laundry within the treating chamber **18**. The amount of laundry may be determined automatically in any of the previously described methods, such as using a weight sensor, or based on sensor output from the motor **88**. The manner in which the amount of laundry is determined is not germane to the embodiments of the invention.

The type of laundry may be determined manually based on user input through the user interface **98** or automatically by the washing machine **10**. Non-limiting examples of types of laundry include cotton, silk, polyester, delicates, permanent press and heavy duty. In one example, the controller **96** may determine the type of laundry based on the cycle of operation selected by the user and optionally one or more settings of the cycle of operation selected by the user. Alternatively, one or more sensors may be used to determine the type of laundry. The manner in which the type of laundry is determined is not germane to the embodiments of the invention.

The desired movement of the laundry may be categorized into one or more of several categories of movement known in the art. Non-limiting examples of movement categories include tumbling, rolling, sliding and satellizing. These are terms of art that may be used to describe the motion of some or all of the items forming the laundry load. However, not all of the items forming the laundry load need exhibit the motion for the laundry load to be described accordingly.

A brief description of each motion will be useful in understanding the term. Tumbling, also referred to as lift and drop, is a condition in which the laundry may be lifted by the rotating drum **16** from a lower position, generally near or at the bottom of the drum **16**, to a raised position, above the lower position, where the laundry is no longer being lifted by the drum **16** and falls within the drum **16**, generally toward the bottom of the drum **16**. The rotation of the laundry articles with the drum **16** may be facilitated by the baffles **22**. During tumbling, the individual laundry articles may move relative to one another such that the articles may rub against each other and may fall onto each other as they fall to the lower position of the drum **16**. This may generate article-to-article friction, which may provide mechanical cleaning action to the laundry articles.

Rolling, also referred to as balling, is a condition in which the laundry may not be lifted by the drum **16** as the drum **16** rotates, such as occurs during tumbling, but rolls or rotates while part of the laundry may still be in contact with the interior surface of the drum **16** and/or the lifter **22**. In this condition, a frictional force may be present that causes the laundry to move in a rolling or folding manner with little or no motion above its horizontal position in the drum **16**. Rolling may occur with laundry items that are too large or heavy to be lifted by the drum **16** or when a laundry item becomes entangled with another item.

Sliding is another condition in which the laundry may not be lifted by the drum **16** as the drum rotates, such as occurs during tumbling, but may remain at or near the bottom of the drum **16**. Sliding differs from rolling in that the laundry does not move in a rolling or folding manner, rather, it slides off the inner surface of the drum **16** as the drum **16** rotates, generally exposing the same face of the laundry to the liquid in the washing machine **10**.

Satellizing is a condition in which the laundry may be held by centrifugal force against the inner surface of the drum **16** as the drum **16** rotates. During satellizing, the motor **88** may rotate the drum **16** at rotational speeds, i.e. a spin speed, wherein the laundry items creating the laundry load in the treating chamber **18** are held against the inner surface of the drum **16** and rotate with the drum **16** without falling. This is known as the laundry being satellized or plastered against the drum **16**. Typically, the force applied to the laundry items at the satellizing speeds is greater than or about equal to 1G. For a horizontal axis washing machine **10**, the drum **16** may rotate about an axis that may be inclined relative to the horizontal, in which case the term "1G" refers to the vertical component of the centrifugal force vector, and the total magnitude along the centrifugal force vector would therefore be greater than 1G.

Each movement category may have one or more subcategories based on the corresponding rotational speed of the drum **16** and/or the amount of mechanical energy imparted to the laundry. Each movement category and/or subcategory may correspond to a cleaning mode that may be provided to the laundry during a cycle of operation.

The controller **98** may control the speed of the motor **88** to rotate the drum **16** at **203** at a default speed based on the cycle of operation and one or more automatic or manually selected settings, such as the amount or type of laundry. The default speed may be based on the speed that typically results in the desired movement of the laundry for a load of laundry having a standard amount and/or a default type and may be determined empirically or experimentally. Alternatively, the default speed may not correspond to a desired movement, but rather correspond to a predetermined speed for initiating the method **200**. There may be a single default speed or a plurality of default speeds based on the selected cycle of operation and/or one or more settings, such as the amount of laundry or the type of laundry.

At **204**, the motor torque may be determined using a motor torque sensor and the motor torque sensor may output a motor torque signal to the controller **96**. The controller **96** may use one or more characteristics of the motor torque signal, such as the amplitude and frequency of oscillations in the motor torque signal at **206** to determine the movement of the laundry. FIGS. **4-6** illustrate exemplary torque signals and drum speed signals corresponding to different movement categories. The data in FIGS. **6-8** may not be indicative of actual data, but is included for the purposes of illustration.

FIG. **4** illustrates an exemplary motor torque signal **110** and drum speed **112** over time corresponding to a rolling movement. As illustrated schematically in FIG. **4**, during rotation of the drum **16**, a laundry article **114** rolls or rotates while part of the laundry article **114** maintains contact with drum **16**, but is generally not lifted above its position near a bottom of the drum **16**. During a phase in which the drum speed **112** is increasing from **0** to a speed **116**, the motor torque signal **110** is also increasing. A non-limiting example of a suitable speed **116** is **28** rpm. Once the drum speed reaches the speed **116**, the drum speed **112** plateaus and the motor torque signal **110** begins to oscillate or ripple. The frequency **118** of the oscillations and the amplitude **120** of the oscillations may be indicative of the rolling movement of the article **114** in drum **16**. The frequency **118** and amplitude **120** of the oscillations indicative of a rolling movement are greater than the frequency and amplitude of oscillation indicative of a sliding movement.

FIG. **5** illustrates an exemplary motor torque signal **122** and drum speed **124** over time corresponding to a tumbling movement. As illustrated schematically in FIG. **5**, during rotation of the drum **16**, the laundry article **114** may be lifted by the baffles **22** from a position near the bottom of the drum **16** to a raised position, where the article **114** is no longer being lifted by the drum **16** and falls within the drum **16**, generally toward the bottom of the drum **16**. During a phase in which the drum speed **124** is increasing from 0 to a speed **126**, which is higher than the speed **116**, the motor torque signal **122** is also increasing. A non-limiting example of a suitable speed **126** is 52 rpm. Once the drum speed reaches the speed **126**, the drum speed **124** plateaus and the motor torque signal **122** begins to oscillate or ripple. The frequency **128** and the amplitude **130** of the oscillations of the motor torque signal **122** are greater for the laundry article **114** in a tumbling condition than the frequency **118** and amplitude **120** of the motor torque signal **110** when the laundry article **114** is in a rolling condition, as described above with respect to FIG. **4**.

FIG. **6** illustrates an exemplary motor torque signal **132** and drum speed **134** over time corresponding to a satellizing movement. As illustrated schematically in FIG. **6**, during rotation of the drum **16** at a satellizing speed **136**, the laundry article **114** is held by centrifugal force against the inner surface of the drum **16**. During a phase in which the drum speed **134** is increasing from 0 to the satellizing speed **136**, which is higher than the speed **126**, the motor torque signal **132** is also increasing. Once the drum speed reaches the satellizing speed **136**, the drum speed **134** plateaus and the motor torque signal **132** also plateaus, with negligible oscillations, indicating the laundry article **114** is in a satellizing movement condition. The frequency and amplitude of oscillations indicative of a satellizing movement condition are lower than the frequency and amplitude of oscillations indicative of a sliding condition.

The controller **98** may monitor the motor torque signal during rotation of the drum **16** when the drum **16** is rotated at a constant speed and determine the frequency and amplitude of oscillations in the motor torque signal. The frequency and amplitude of oscillations in the motor torque signal may be determined after a predetermined period of time after the drum **16** starts to rotate, after the drum **16** reaches a predetermined speed, or after a rate of change in the speed of the drum **16** reaches a predetermined threshold. The motor torque signal may be monitored continuously or intermittently during rotation of the drum **16**. The frequency and amplitude of the oscillations may be determined using any known mathematical algorithm, and may be based on a single measurement or multiple measurements in which an average frequency and/or amplitude is determined.

In one example, the frequency may be determined by measuring the time period between successive maximum and minimums in the motor torque signal. In another example, at least a portion of the motor torque signal may be fit to an equation and the frequency determined by the controller **98** from the equation. The amplitude of the motor torque oscillations may similarly be determined based on the fit of at least a portion of the motor torque signal to an equation. In another example, the amplitude may be determined by determining the difference or an average difference between a maximum and minimum of the torque signal. In another example, the frequency and amplitude of the motor torque oscillations may be determined by converting the motor torque data from the time domain to the frequency domain according to any known mathematical method, such as a Fast Fourier Transform (FFT). One such method is that described in U.S. Patent Publication 20100263136, entitled "Method and Apparatus for Determining Laundry Load Size," filed Apr. 16, 2009 and assigned to the present assignee. One or more filters or data smoothing algorithms may be applied to the motor torque signal to aid in analysis of the signal, as is known in the art.

Once the frequency and amplitude of the motor torque signal have been determined, the controller **98** may compare the determined frequency and amplitude to a pair of frequency and amplitude reference values to determine the movement of the laundry. A plurality of frequency and amplitude reference values may be determined empirically or experimentally and stored in the memory **100** of the controller **98**. The reference values may be stored in a look-up table of corresponding movement categories that the controller **98** may consult. In another example, the plurality of frequency and amplitude reference values may be used with one or more functions for determining the movement category of the laundry. The determined frequency and amplitude values may be plugged into the function(s) as input and used to generate an output that corresponds to the movement category of the laundry.

At **208**, the controller **98** may use the determined movement of the laundry at **206** to control the motor speed to obtain the desired movement of the laundry. The movement condition of a load of laundry at a given drum rotation speed may vary depending on the characteristics of the load. Characteristics such as the amount of the laundry, the volume of the laundry, the amount of liquid absorbed by the laundry and the fabric type of the laundry may effect the movement of the laundry at a given drum rotational speed. The controller **98** may increase or decrease the rotational speed of the drum **16** depending on the determined movement category of the laundry at **206** to obtain the desired movement.

For example, the controller **98** may be programmed with a motor control algorithm for determining how to change the drum rotational speed to obtain the desired movement based on the determined movement and characteristics of the laundry load. The drum rotational speed, determined movement and one or more characteristics of the laundry load, such as amount or fabric type, may be input into the motor control algorithm and the algorithm may provide an output signal corresponding to either an increase in drum rotational speed or a decrease in rotational speed. It is also within the scope of the invention for the determined frequency and amplitude to be input directly into the motor control algorithm without determining the movement of the laundry. The motor control algorithm output may correspond to a desired speed setting and the motor **88** may control the drum **16** to rotate at the desired speed setting. Alternatively, the motor control algorithm output may correspond to incrementally accelerating or decelerating the drum rotational speed. The method **200** may be initiated one or more times during a speed plateau in the acceleration/deceleration of the drum **16** to determine when the determined movement of the laundry corresponds to the desired movement of the laundry.

The method **200** provides a method in which the controller **98** may determine the movement of the laundry within the drum **16** in real time and adjust the rotational speed of the drum **16** to provide a desired movement of the laundry. In this manner, because the movement of the laundry correlates with the mechanical action imparted to the laundry, the rotational speed of the drum **16** may be adjusted during a cycle of operation to provide each laundry load with the desired amount and sequencing of mechanical action based on the selected cycle of operation and various settings.

FIG. **7** illustrates a control system **300** that may be used to control the rotation of the drum **16** to impart the desired amount and sequencing of the mechanical action imparted to the laundry load based on the user selected cycle of operation and/or settings to provide the desired treating performance. While the control system **300** is illustrated as a closed loop feedback system, it is also within the scope of the invention for the control system **300** to be an open loop system. The control system **300** may be used in combination with the method **200** of FIG. **3** for determining the movement of the laundry. It is also within the scope of the invention for other methods of determining the movement of the laundry to be used with the control system **300**.

Information **302** about the laundry load and one or more components of the washing machine **10**, non-limiting examples of which include the rotational speed of the drum **16**, motor torque, motor power, drum acceleration, sensor information, and characteristics of the laundry load, may be used to determine the movement of the laundry **304** using the method **200** of FIG. **3**, for example. The determined movement of the laundry **304** may be used by a mechanical action estimator **306** to estimate the mechanical action imparted to the laundry load. The mechanical action estimator **306** may determine a cumulative amount of mechanical action over a predetermined period of time and/or a magnitude of mechanical action at a specific time.

The selected cycle of operation and any automatic or manually selected settings **308** may be used to determine the desired mechanical action **310** to be imparted to the laundry, which may be used to determine the desired movement of the laundry **312**. The desired movement of the laundry **312** and the determined movement of the laundry **304** may be provided as input to a control algorithm **314** to determine how to change the drum rotational speed so that the determined movement of the laundry **304** satisfies the desired movement of the laundry **312**. The determined mechanical action may also be provided to the control algorithm **314** by the mechanical action estimator **306**. The control algorithm **314** may provide as output to a motor control algorithm **316** a desired movement of the drum **16**, such as speed, duration and direction of rotation of the drum **16**. The motor control algorithm **316** may use the control algorithm output as well as the information **302** to determine how to control the motor **88** to provide the desired movement of the drum **16** during one or more phases of the selected cycle of operation.

The control system **300** may be used to control the motor **88** to rotate the drum **16** to provide the desired movement and mechanical action to the laundry. Using the closed loop feedback control system **300**, the control of the motor **88** may be adapted during the cycle of operation to account for changes in the system, such as changes in weight as liquid is absorbed or extracted from the laundry, or changes in the power consumption of the motor **88**, to provide the desired movement and mechanical action to the laundry. In this manner, the control system **300** may maintain the laundry in the desired movement category so as to provide the desired treatment outcome based on the selected cycle of operation.

For example, a selected cycle of operation may correspond to a predetermined cumulative amount and/or magnitude of mechanical action to be imparted to the laundry. The control system **300** may be used to control the motor **88** to rotate the drum **16** to move the laundry according to a plurality of movement categories to provide the desired mechanical action corresponding to the selected cycle of operation. The sequencing and duration of the different movement categories, such as rolling, tumbling and satellizing, may be controlled in real time based on the inputs into the closed loop feedback control system **300** at different points during the cycle of operation. The mechanical action estimator **306** may be used to monitor the cumulative amount and/or magnitude of mechanical action imparted to the laundry and the control system **300** may use the estimated mechanical action to adjust the control of the motor **88** to provide the desired cumulative amount and/or magnitude of mechanical action.

To the extent not already described, the different features and structures of the various embodiments may be used in combination with each other as desired. That one feature may not be illustrated in all of the embodiments is not meant to be construed that it cannot be, but is done for brevity of description. Thus, the various features of the different embodiments may be mixed and matched as desired to form new embodiments, whether or not the new embodiments are expressly described.

While the invention has been specifically described in connection with certain specific embodiments thereof, it is to be understood that this is by way of illustration and not of limitation. Reasonable variation and modification are possible within the scope of the forgoing disclosure and drawings without departing from the spirit of the invention which is defined in the appended claims.

What is claimed is:

**1**. A method for operating a laundry treating appliance having a drum at least partially defining a treating chamber for receiving laundry for treatment, a motor operably coupled to and rotating the drum, a controller coupled to and controlling the motor, and a user interface operably coupled to the controller, wherein the controller controls the motor according to a cycle of operation selected via the user interface, the method comprising:

establishing a desired movement of the laundry within the treating chamber;

controlling the speed of the motor to control the rotational speed of the drum by the controller providing a speed control signal to the motor;

receiving by the controller a torque signal indicative of the torque of the motor;

monitoring by the controller of an amplitude and a frequency of a ripple in the torque signal;

determining by the controller a category of movement of the laundry from a predetermined group of movement categories by comparing the monitored amplitude and frequency to corresponding pairs of amplitude and frequency reference values for each of the movement categories, the movement categories selected from the group consisting of sliding, rolling, tumbling, and satellizing; and

controlling by the controller the speed of the motor until the determined category of movement of the laundry satisfies the desired movement of the laundry.

**2**. The method of claim **1** wherein establishing the desired movement of the laundry is based on an amount of mechanical action to be imparted to the laundry.

**3**. The method of claim **2** wherein establishing the amount of mechanical action is based on a cycle of operation selected via the user interface or a fabric type of the laundry.

**4**. The method of claim **3** wherein establishing the amount of mechanical action is based on both of a cycle of operation selected via the user interface and a fabric type of the laundry.

**5**. The method of claim **1** wherein establishing the desired movement is based on a cycle of operation selected via the user interface or a fabric type of the laundry.

**6**. The method of claim **5** wherein establishing the desired movement is based on a cycle of operation selected via the user interface and at least one of a fabric type of the laundry, an amount of laundry, an amount of laundry and absorbed liquid, or combinations thereof.

**7**. The method of claim **1** wherein the movement categories comprise at least three of sliding, rolling, tumbling, or satellizing.

**8**. The method of claim **7** wherein the movement categories comprise at least sliding, rolling, tumbling, and satellizing.

**9**. The method of claim **7** wherein the rolling movement category has a greater amplitude and a greater frequency than the sliding movement category.

**10**. The method of claim **9** wherein the tumbling movement category has a greater amplitude and a greater frequency than the rolling movement category.

**11**. The method of claim **10** wherein the satellizing movement category has a lower amplitude and a lower frequency than the sliding movement category.

* * * * *